The Files 30 September 1957

[redacted] 25X1A9a

Trip Report - [redacted] 25X1A5a1

A trip was made to [redacted] 25X1A5a1 on September 18 - 24 to determine the status of the TP-3, 12 volt DC motor. The main objectives were:

(1) Observe measurements on motor #6827 made at [redacted] 25X1A5a1 and correlate them with the measurements made at the Laboratory.

(2) Determine the feasibility of magnetizing the motor field magnets from the inside in order to reduce the motor leakage flux which sets up a high residual magnetism in the TP-3 magnetic circuit.

(3) Determine the relative importance of such factors as field flux density versus armature turns and efficiency; armature and governor brush drop versus motor efficiency, and humidity versus oxide build up on brushes and governor contact. Determine the optimum armature and field for least change in speed over the torque voltage range for an ungoverned motor. Consider the governor in relation to the motor. Determine the difference in speed variations with several magnets, armatures, and governors to determine the statistical spread in motor speed versus torque and voltage range.

(4) Make recommendation as to relaxation or tightening of the specifications or determine the feasibility of using transistor voltage regulator circuits with and without the Lee governor or abandoning the DC motor. Make recommendation as to the employment of a synchronous, a slip induction, or other type motor capable of being driven from a stable transistorized power oscillator. Discuss changes in the specifications and the production status.

1.1. Correlation of Measurements: Measurements of speed versus torque and voltage were made on our original sample motor #6827. Our method of speed measurement using a light chopper and photocell is four times as accurate as their speed measurements counting at a basic rate of $\frac{2100}{60}$ or 35 cps $\pm$ 1 part.

Torque versus current and voltage correlated very well while speed variations ranged up to .5% higher on the low torque, high voltage side. [redacted] does not have a temperature chamber that may be adequately controlled. One is available at [redacted] but no temperature runs have been made in the past on any of the motors presented under the specifications.

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2.1. Magnetic Measurements: After some days' delay a fixture was completed which enabled the magnetization of the one piece cast (2 poles) Alnico V field magnet from the inside. The leakage flux density was measured at the periphery of the front frame and then compared at the same location to an externally magnetized unit. The internally magnetized magnet leakage field was found to be reduced by a factor of three times over externally magnetized magnet.

2.2. The average internal flux density of the externally magnetized magnet was found to be higher than the internally magnetized unit with large peak fluxes being found off the pole centers. The motors using this magnet exhibited a higher speed than the internally magnetized units which exhibited a lower but more evenly distributed field. Internally magnetized field magnets with the same armatures show less (governor removed) speed variation over the torque-voltage range. The field of motor #6827 employing an externally magnetized magnet was apparently incrementally demagnetized to a lower point on the B-H curve by degaussing. Its speed was in between that of the fully internal and externally magnetized magnets. Production units #6829 and #6839 employing externally magnetized magnets exhibited the greatest amount of armature detent action and is directly attributed to peak off center flux concentrations. The original sample #6827, because of degaussing was noticeably less in armature detent action and in no load current. A series of measurements made on September 19th established an important criteria. The internally magnetized units (governor removed) exhibited less speed variation over torque range with the same armature. This speed change averaged 450 rpm with a change of 80 ma while the externally magnetized unit exhibited a change of 883 rpm and a current change of 110 ma.

2.3. Working at a lower flux density (and less magnetic drag due to armature detent action) yields improved speed regulation. The no load current is influenced strongly by the magnetic drag of the detent action. The least change in speed, change in current and minimum no load current over the torque range

occurred on a sample of 5 internally magnetized magnets. The above changes were found to be substantially uniform.

2.4. The magnetic material is purchased from [redacted] print B1212-175. The residual induction and coercive force specified for this magnet was checked against Arnold Engineering data for Alnico V and found to be almost identical. The magnets are shipped demagnetized. Two-piece magnets could have been used in these motors without problems in magnetization but the single cast piece magnet is less expensive. The higher flux density which may be obtained is not needed. 25X1A5a1

The relationships between armature turns, field flux density, field stability and locked rotor conditions will be discussed subsequently.

3.1. Motor Governor Brush Measurements: To determine the relative voltage drops across the armature and governor brushes, the motor magnets were removed and the motor driven at 2100 rpm by another motor. In the driven motor a current of 125 ma was caused to flow through the armature and governor in series. The relative voltage drops were recorded and the resistance calculated for two types of brushes. The first set of brushes as supplied on unit #6827 are of carbon and of rather soft consistency. The resistance of the armature brushes and governor brushes combined was recorded as three times the armature resistance itself. The resistance of high copper content brushes as supplied on the production prototype is approximately equal to the armature resistance. The governor brush drops are twice the motor brush drops. The efficiency of the motor with high resistance brushes is 20%. The armature efficiency without the governor is 46%. Using high copper content brushes the efficiency is increased to 36.5%. The resistance of the carbon governor brushes increases by a factor of 1.44 between a dirty governor commutator and a clean commutator while the higher copper content brushes between the dirty and clean commutator condition, changed by a factor of 1.5, showing an equal rate of increasing resistance. The absolute relative resistances of the carbon to the carbon-copper brushes is 3:1. The carbon brushes account for a loss in motor efficiency of 26% under nominal operating conditions.

3.2. Oxide Built Up On Governor Contact: In several instances, under high humidity conditions, as when motors are returned from cold temperature, speed variations were noticed on unit

#6827 and on those units which were supplied without a governor resistor, the motor would not start. This condition exists due to oxide build up on the governor contacts and commutators. This problem was discussed with [redacted] engineers and there appears to be no specific answer (the housings are now completed) except to seal the rear end cover and permit the motor to breathe only through the front bearing. This sealing is done with a latex compound and applied to the area adjoining the rear cover and the motor frame. It is only a stop-gap solution at most. 25X1A5a1

3.3. Optimum Armature: High copper content brushes replaced the soft carbon brushes on the production prototypes. This increased the effective armature voltage and speed. Since the speed increases with demagnetizing of the field, the governor (same Lee type as used on engineering samples) was required to decrease an initial speed above its optimum upper operating range. The effect of trying to govern under these conditions leads to weighting the governor leaf and removal of the governor resistor which is not in the recommended procedure as published by Lee.

The armature turns must be increased. A sample armature wound for another motor of this series and containing twice as many armature turns as the previous armature was mounted and its speed recorded as too low. The field was demagnetized incrementally and the speed change over torque voltage range was recorded. The speed change between high torque-low voltage and low torque-high voltage remained constant while the absolute speed was increased 10%. At a demagnetization voltage of 50 volts as applied to [redacted] fixture TA-150 25X1A5a1
the field was considered optimum. The governor was placed on the unit and the speed was within $\pm$ 1% over a torque range of .1 to .25 oz./in. and a voltage range of 10.8 to 13.2 volts. The field demagnetization was, however, only five demagnetization volts from the point at which larger change in speed over the torque and voltage range would occur. A compromise armature built to approximately 100 turns with #36 wire is being wound. The stability of the operating point will be checked by plotting the change in speed as a function of demagnetization and checking for an increase in speed after imposing repeated locked rotor conditions.

3.4. The addition of the governor assembly to an externally driven motor causes an increase in loading of 30 ma at 2100 rpm. This is equivalent to .24 oz./in. which is 100% of nominal load torque of the TP-3 mechanisms. It is apparent that the load the governor puts on the motor is equal to the load that is required to operate the TP-3 mechanism. Moreover, the hash, unstable operation of the governor contact and brushes makes it highly desirable that the governor be improved or removed and speed regulation accomplished by either voltage or frequency control.

4.1. Speed Regulation by Voltage Control: With the new armature and the governor removed the operating voltage for nominal load and speed will be between 7 and 8 volts. [redacted] is to run a sample of five units to determine how close they can hold the motor speed at a specific voltage and load and without the governor. This condition will also be so chosen as to present to the governor, if used, the best operating condition possible and prevent a wide variance in motors before the governor is applied. Statistical information will be compiled from this data. Voltage regulation circuits have been designed in the Laboratory which can regulate the input voltage over the range of 10.8 to 13.2. Additional circuitry is now being tested which will sense the change in load and increase the regulated voltage to maintain the speed with variation in load. A potentiometer will be available to adjust the motor while running and the transistor circuitry will be housed inside the motor rear cover in the space vacated by the governor and the governor brushes. 25X1A5a1

4.2. Speed Regulation by Frequency Control: Our work with the unijunction transistor in low frequency audio oscillator circuits has demonstrated that an accuracy of ± 1% can be obtained. High efficiency class B push-pull stages capable of supplying the required power for this motor is easily obtained. The efficiency of the synchronous motor is inherently poor and it is felt that a slip induction motor with a small amount of frequency control is most likely to succeed.

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4.3. Production Status: [redacted] has all the motor parts processed except for winding of the armatures. Once the decision is made as to whether the new motor with the governor is acceptable or voltage regulation circuitry is entirely feasible and reliable, ten units can be completed in two weeks. Decisions on these matters are expected by October 7th.

4.4. Specification: Measurements at the Laboratory to -10° C indicate that the maximum load expected on the motor will be .25 oz./in. It is recommended, therefore, that the specification in this respect be so relaxed. The manufacturer requests some relaxation in the mechanical specification but final agreement has not been reached.

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